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Defence and Civil

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October 1982

DCIEM Report No. 82-R-54

EVALUATION OF HIGH PERFORMANCE AIRCREW HELMETS AND OXYGEN MASKS

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LIST OF ABBREVIATIONS

ACM	air combat manoeuvering
ADV PUB	advisory publication
ASCC	Air Standardization Coordinating Committee
cd	candela
CF	Canadian Forces
CFB	Canadian Forces Base
cm	centimetre
C of G	centre of gravity
D	helmet designation suffix indicating dual visor
DAS Eng	Director of Aerospace Support Engineering
DCIEM	Defence and Civil Institute of Environmental Medicine
deg	degrees
G	gravitational acceleration
J	joules
m	metre
MLSD	Medical Life Support Division
mm	millimetre
N	newton
rad	radian
RAF	Royal Air Force
s	standard deviation
S	helmet designation suffix indicating single visor
TPL	thermal plastic liner
USAF	U.S. Air Force
USN	U.S. Navy
VTAS	visual target acquisition system
x	mean value

ABSTRACT

The requirement for a new oxygen mask and helmet for use by Canadian Forces (CF) aircrew in the air combat manoeuvering (ACM) role was indicated in 1978. Initial studies were conducted to identify shortcomings of the current assembly and to allow aircrew to rank design characteristics. Four helmet and four oxygen mask types were ultimately selected for comprehensive evaluation. A flight trial involving 48 aircrew flying primarily CF-5 and CF-104 aircraft was conducted at CFB Cold Lake in order to determine aircrew preferences for overall and specific designs, including the preference for single or dual visor. Maintenance implications of all test equipment were also evaluated. Equipment properties were determined in laboratory studies conducted primarily at DCIEM. It is concluded that the best assembly for aircrew of CF ACM aircraft is an extended PRK 37P helmet shell with thermal plastic liner, integrated chin/nape strap, cutaway PRU 36P (dual) visor and modified type W oxygen mask. However, deficiencies related to the visor weight, centre of gravity and profile should be resolved.

1. INTRODUCTION

Over the past ten years, air forces in North America have come to realize that their current aircrew helmets are inadequate in the high performance aircraft, particularly during air combat manoeuvering. The U.S. Navy (USN) was the first to commence investigation of new helmet options for this environment. Recently U.S. Air Force (USAF) Tactical Air Command has initiated a program to replace their high performance aircrew helmet. The requirement for a new aircrew helmet was stated within the Canadian Forces (CF) three years ago and a request (1) was made to replace our old A13A oxygen mask.

At the direction of the Director of Aerospace Support Engineering (DAS Eng) (2), the Medical Life Support Division (MLSD) of the Defence and Civil Institute of Environmental Medicine (DCIEM) conducted two studies. The first of these was a survey to identify the nature of the shortcomings of the current DH 41-2 aircrew helmet and A13A oxygen mask with Pate suspension and to determine potential improvements. Aircrew believed that the helmet was deficient in comfort and visual field and that the oxygen mask was difficult to position and unstable during air combat manoeuvering (ACM) (3). In the second study, high performance aircrew rank-ordered helmet design characteristics (4). Visual field was considered to be the most important characteristic, followed immediately by comfort. Significantly, the aircrew ranked protective characteristics below most others.

It was decided that the plan to improve the CF high performance headgear would take two routes (5). The first was the design of an interim modification to the current assemblies that would address the more critical requirements of visual field and stability under "G" loading, but require minimal logistic support and implementation time. The second was the design or selection of an aircrew helmet which would be comfortable and stable, cause minimal visual field restriction, and not compromise protection.

After a year of work, two interim designs were selected for flight trial (6). At that point, the helmets designated as potential long-term replacements were also ready for operational evaluation, and a flight trial was initiated.

A preliminary laboratory evaluation was conducted to ensure that flight safety requirements were met. A more comprehensive evaluation was conducted after the operational evaluation. Concurrently, a second flight trial involving only the two leading helmet contenders was conducted to increase the number of aircrew exposures, detect longer term equipment deficiences and highlight maintenance difficulties.

2. OBJECTIVES

The general objective of this evaluation program was to determine and recommend the best helmet and oxygen mask for CF use in the air combat environment (7). The specific objectives were to:

a. determine aircrew preference among overall and specific designs;
b. measure equipment characteristics;
c. evaluate maintenance implications

3. EQUIPMENT SELECTION

3.1 Helmets and Visors

The initial phase of the helmet selection process was the conclusion of an evaluation of the most commonly used aircrew helmets in North America, which had been initiated prior to this program. This evaluation included the HGU 26P, DH 151 (found to be superior to the USN APH-6 by the USN (8)), HGU 39P, SPH-4 and DH 41-2. It was demonstrated with the DH 151 and HGU 26P that lightweight high performance helmets could provide reasonable levels of hearing and impact protection. The SPH-4 and HGU 39P were designed for use in rotary wing aircraft.

Within the USAF, three helmets (Sierra Lightweight, HGU 48/P and HGU 53/P) were developed to address increased stresses on aircrew in new generation high performance aircraft. In the seventies, the USN developed a new series of helmets (HGU 33/P, HGU 34/P and HGU 35/P) attempting to utilize as few helmet shells and liner systems as possible to accommodate all Naval aviators. The Royal Air Force (RAF) has recently developed one new helmet (MK4 Flying Helmet), while the CF has developed three (DH 186, DH 200 and DH 41-4). Described in Annex A, the above helmets were selected for or excluded from detailed evaluation as follows:

a. selected

1. HGU 33/P with V-Tec and Thermal Plastic (TPL) Liners and EEK 4AP single and PRU 36P dual visors
2. DH 186 with EEK 4AP single visor
3. DH 200 with EEK 4AP single and PRU 36P dual visors
4. DH 41-4 with CF1 single and CF2 dual visors

b. excluded

1. Sierra Lightweight - not available and results of USAF flight trial unfavourable
2. HGU-48/P - interim modification of HGU-26/P
3. HGU-53/P - not available
4. HGU-34/P - poor comfort relative to HGU-33/P
5. HGU-35/P - high breathing resistance which does not meet physiological specifications of ASCC Advisory Publication (ADV PUB 61/3A)
6. MK4 Flying - not available

For the purposes of this report, helmet designators will include a suffic "S" or "D" to indicate specifically single or dual visor, respectively (i.e. HGU-33/PS = HGU-33/P helmet with single visor).

All of the helmets tested were acquired with a matt gray paint scheme, which is not only aesthetically pleasing (14) but also provides a good balance between low conspcuity and low absorption of solar radiation. Except for the DH 41-4 helmets, another common feature was the extension of the protected area to cover the ears. This was done to provide a rigid attachment point for the oxygen mask and a means of mounting the earcups rather than to protect the ears from impact injury.

3.2 Oxygen Masks

CF aircrew were dissatisfied with the A13A oxygen mask and Pate suspension as were USN and USAF aircrew with the MBU 3/P and MBU 5/P masks, respectively. The CF combined the A13A mask with a modified MBU 3/P suspension, which was considered superior to the Pate suspension (6,14). The USAF and USN combined their resources to produce a common mask designated the MBU 12/P (used in future reference) and MBU 14/P, respectively. The RAF are currently using the P/Q mask and have for over 20 years. A derivative of the P/Q, called the W mask, was recently developed by the British Ministry of Defence, Procurement Executive. Described in Annex A, these four oxygen masks were selected for evaluation.

4. METHODS

4.1 Operational Evaluation

A fifteen-week operational trial was conducted at Canadian Forces Base (CFB) Cold Lake, where the primary CF air combat aircraft CF-5 and CF-104 are flown. Forty-eight aircrew participated, each assessing up to four helmet types, one visor configuration (single or dual) and one oxygen mask type. The aircraft types, number of aircrew and units involved are summarized in Table 1. The participants were divided into groups and subgroups so that each helmet/visor/oxygen mask configuration could be adequately assessed over a twelve working day period. Details of the trial design are presented in Annex B. A separate ten-week operational trial was added to the maintenance evaluation (see 4.3) after the TPL helmet liner became available.

Table 1 - Trial Aircraft and Aircrew

Aircraft Type	No. of Aircrew	Unit
CF-104	10	417 Sqn
CF-5	31	419, 434 Sqns
CF-104, CF-5, CT-133	7	Aerospace Engineering Test Establishment (AETE)

Three questionnaires (Appendix to Annex B) were used focussing on the helmet, oxygen mask and visor configuration. This enabled aircrew to:

a. indicate their preferential ordering of helmets worn to that point in the trial;

b. evaluate the specific performance of a helmet or mask in terms of the qualities specified in the Statement of Requirement;

c. express a general opinion of the test equipment and compare it with the current equipment; and

d. explain their preference for a dual or single visor

The distribution of aircrew responses is included in Annex B.

The helmet characteristics which are considered critical to flight safety and were examined in the preliminary laboratory evaluation include field of vision, impact protection, weight, hearing protection, stability and retention during windblast. Testing procedures were the same as those used during the

main laboratory evaluation. Hearing protection was previously documented for the HGU-33/P (15), DH 200 (same as that of the HGU-33/P) and DH 41-4 (same as DH 41-2) (16).

4.2 Laboratory Evaluations

The protective and physical characteristics of the candidate helmets and oxygen masks were determined in a series of laboratory evaluations. The helmet evaluation procedure conformed to that of the Air Standardization Coordinating Committee (ASCC) draft Air Standard 61034/4 entitled "Evaluation Procedures for Flight Helmets". Evaluations conducted at DCIEM include impact, hearing and facial protection, retention, field of vision, centre of gravity, weight and profile. Test procedures are shown in Annex C. Evaluation of respiratory impedance was carried out by Group Captain J. Ernsting (RAF) at the USAF School of Aerospace Medicine (11). The evaluated items had been in service for a minimum of eight weeks prior to the laboratory evaluation to simulate in-service condition. Obvious mechanical damage that would preclude assessment of a characteristic was corrected.

4.3 Maintenance Evaluation

The maintainability of the trial helmets was assessed by two methods. The safety systems technicians conducting the fitting and maintenance of the test equipment during the operational evaluation kept a log of fitting and maintenance deficiencies. 434 Tactical Fighter Squadron participated only minimally in the operational evaluation and were selected to conduct a follow on maintenance evaluation. Two of each of the four leading contenders (DH 200S, DH 200D, HGU-33PS and HGU-33PD) as well as two of each of the candidate oxygen masks were included in this evaluation. The oxygen masks were assigned to participants such that a mask worn with the single visor version of one helmet type was worn with the dual visor version of the other type.

Two forms of report were used. The aircrew completed the helmet and oxygen mask questionnaires used in the operational evaluation less the rank ordering section, and the safety systems technicians involved in the maintenance were debriefed by a DCIEM representative at the conclusion of the trial.

5. RESULTS AND DISCUSSION

5.1 Operational Requirements

The highlights of operational, laboratory and maintenance evaluations results are presented in discussion related to operational requirements, while extensive detailed results are presented in Annex D. The draft Statement of Requirement (Preliminary) lists a number of air combat helmet and oxygen mask system requirements, each discussed separately as follows:

a. "deliver to the wearer the required breathing gas throughout the flight envelopes of current and planned ejection seat aircraft."

There are two specific environments requiring physiological protection to be provided by the oxygen system - at altitude and with +Gz acceleration forces (ACM). Flight in CF aircraft is currently not normally conducted above an altitude of 48,000 feet, but there is a potential requirement for a higher altitude capability. Unacceptable outboard leakage occurs with the MBU 12/P and A13A oxygen masks at regulator delivery pressures corresponding to altitudes below 48,000 feet. Seal integrity of P/Q mask and, by similarity, the W mask has been

demonstrated to 80,000 feet (24), the maximum foreseeable requirement. During air combat, aircrew perform the L-1 or M-1 straining manoeuver to improve G tolerance. These manoeuvers require peak flows in excess of 170 litres per minute. The W and P/Q masks provide less breathing impedance at all flow rates than suggested by a proposed amendment (25) to ASCC Advisory Publication (ADV PUB) 61/3A. Both the MBU 12P and A13A exceed the limits specified in the ADV PUB at all flow rates. It is concluded that only the W and P/Q masks satisfy the breathing gas requirement.

b. <u>"provide the wearer with the necessary communications for safe operation and control of the aircraft."</u>

Communications were assessed solely by means of aircrew opinion. All helmets are equipped with H143 A/C earphone elements, for which there are no critical deficiencies. The DH 41-2 helmet is considered to satisfy the communication requirement. By either similarity or superior results, all other helmet types also satisfy the requirement. It is noted that the results show that communication effectiveness is adversely affected by poor sound attenuation qualities. The A13A mask, which meets the standard, was rated best by aircrew, while the differences are considered negligible for the P/Q and W and marginal for the MBU 12P. While the MBU 12P and A13A both use the M110 microphone, the different ratings are ascribed to the positioning of the microphone with respect to the mask valving. Further assessment would be required to confirm this problem and, if so, identify a solution. "Garbled" transmission reported by one respondent resulted from moisture between the microphone wiring harness contacts. An appropriate seal could be provided. The sensitivity of the W mask was adversely affected by a modification which was required to match impedance. A change in microphone windings would address this deficiency. In summary, the communications requirement is or could be met by all masks except the MBU 12/P, which would require further assessment.

c. <u>"provide impact protection at least equal to that of the current system."</u>

A test impact energy of 90 joules (J) on a flat anvil is considered to be a reasonable estimate of the impact energy which an untrained parachutist (aircrew) could experience on unbroken terrain. Maximum peak acceleration criteria for helicopter helmets is indicated by Slobodnik (26), who suggests that cerebral concusion may occur at peak accelerations greater than 150 G. This provides a basis for protective headgear selection. It is clearly unacceptable to allow aircrew to become concussed and, hence, incapacitated during the post-ejection survival phase. Review of Slobodnik's data indicates that the 150 G criteria is based primarily upon side and rear impact requirements. The rear site impact case of Slobodnik in which approximately 150 G were transmitted resulted in dazing only and not incapacitation. It is considered that a maximum peak acceleration criteria of 200 G at the crown, rear and front sites is appropriate to the high performance environment. An investigation of helmet damage that occurred during ejection showed that side impact is not likely to occur. The 90 J impact energy is considered excessive at the side site, hence for impacts of this magnitude the 200 G criteria was again used.

The impact protection of the DH 41-4 helmet is the same as that provided by the current DH 41-2. Comparison of the mean peak acceleration of the contending helmets to those of the DH 41-4 reveals that none of the helmets transmits a lower peak acceleration at all sites. Conversely, all of the helmet types perform better than the DH 41-4 at one or more sites, and they all transmit accelerations greater than 200G during impacts at two or more sites, typically front and rear.

The HGU 33P helmet with TPL transmits slightly more than 200G at the crown and side impact sites. It is within 30% of the best performers at both of these sites. This helmet meets the criteria as well as provides much superior protection to that of all other helmet types at both the front and rear sites. It is noted that the rear site is of particular concern in the F-18, in which aircrew have suffered concussion due to impact against the seat headrest. Finally, the peak acceleration variance between individual HGU 33P helmets with the TPL is small and, in general, very much less than that of other helmet types. This repeatability occurs because the impact protection provided by the foamed polystyrene liner is not affected by fitting the TPL.

Deficiencies of the DH 41-4 are surprising and concerning. Protection is poor at both the front and rear test sites, which transmit about +300 G or more. This is a direct result of the design of the suspension system, which is mounted to the interior of the shell about the periphery and which provides minimal stopping distance in that area.

The DH 186, also a suspension helmet, offers acceptable protection at the front site. This is achieved because 1.6 cm of expanded polystyrene is inserted in this area.

It is concluded that, while only the DH 41-4D helmets provide equivalent impact protection to that of the DH 41-2, the overall protection provided by the HGU 33P with the TPL is superior.

d. <u>"be retained during ejections, within acceptable wearer tolerance throughout the envelope of current and planned ejection seats."</u>

Windblast evaluations neither strictly replicate the conditions encountered by the helmet and oxygen mask during ejection, nor show conclusively that a particular helmet and mask will be retained during ejection at a comparable dynamic pressure. They are, however, a good method for comparison of helmet and oxygen mask retention characteristics. The results of the windblast trials conducted indicate that retention is directly affected by such factors as liner design, nape strap design, visor configuration, mask attachment and mask facial coverage.

The suspension helmets (DH 41-4, DH 186) were displaced less than the contact helmets (DH 200, HGU 33P) likely due to positive securing action of circumferential strap (DH 41-4) and peripheral fitting pads (DH 186) which apply pressure directly to the frontal and occipital areas. Neither of the contact helmets apply any gripping force on the head in these areas. The enhanced retention may have been a result of the earcups being well secured to the head by the chin strap and nape strap for the DH 41-4 and the inflexibility, tightness and donning/doffing difficulties for the DH 186.

The four helmet types each incorporate a different nape strap arrangement. The HGU 33P, fitted with a fixed length linear nape strap, performed the worst overall. The DH 200, with the same shell, performed significantly better. The dual line integrated nape-chin strap in the DH 200 moves the centre of fixture below the occiput, thus restricting upwards motion of the helmet at the rear. This is reflected by the mean posterior displacements which occurred during windblasts of the helmets with no oxygen mask. Of the suspension helmets, the DH 41-4 had much less posterior displacement than the DH 186. The DH 186, with no nape strap, has a rear fitting pad just below the point of maximum head contour, while the DH 41-4 has an angled nape strap positioned much lower and

Denmark and one Sea King off Nova Scotia).

SEA STATE AND WEATHER CONDITIONS

Generally, sea state and weather conditions for all sea water accidents were reasonably good. In only three cases was the wind reported as high as 21 knots, 25 knots and 18-27 knots. Where other Boards reported such information, the winds were in the range 5-15 knots; three cases were reported with wave height as high as 4-6 feet and one case 3-6 feet. Finally, height of swell was also not severe, the maximum reported being three cases of 5-7 feet, 6 feet and 6-9 feet. In the case of one of the Voodoos which crashed into the Georgia Straits, off Vancouver Island, the wave produced by the crash was in the order of eight to ten feet and there was one comment by the pilot that the liferaft rode this wave well.

If one considers sea water temperature, outside air temperature, wave height, swell height and wind where reported and where not, it can be concluded that sea conditions were generally good and probably contributed to the number of survivors. In the last 20 years of peacetime operation, both the lifepreserver, liferaft and associated equipment have never been subjected to a severe sea state.

FRESH WATER LAKE AND RIVER CONDITIONS

Of the ten fresh water accidents, little detail of lake or river conditions was included in the Boards of Inquiry; however, from analysis of the data, it can be reasonably concluded that in three cases (2 Freedomfighters and a Canuck) where the pilots did not attempt to eject, the lake or river conditions were not a factor in survival. Also, in the Tracker accident in mid-Ontario in September, the lake was warm and the crew waded/swam ashore; therefore, the lake conditions did not pose a threat to the crew.

Mishaps have occurred to five single engine Otters. In four cases, the crew could consider themselves very lucky to have survived. The first case was an Otter that broke through the ice on a lake in Quebec in January. The crew were wearing no lifepreservers, and the wind was reported as 15-20 mph and the outside air temperature as -18 to -20 degrees C. One pilot swam to the ice and scrambled ashore, while the other pilot walked ashore from the wingtip.

The second Otter accident occurred during a familiarization flight and water landing on choppy water with whitecaps noted on the Ottawa River; the wind was 20 mph. Two of the crew were blown ashore in the liferaft, two were taken ashore in a private boat, and two swam ashore. The outside air temperature was reported as 9 degrees C. There was no recording of the river temperature.

The third Otter accident occurred during an ice condition check on a lake in Ontario in January where, on reducing speed, the aircraft broke through the ice. Three crew jumped in the water and swam to the ice, while three walked ashore on the ice. There were no recordings of weather or lake conditions for that day in the Board.

The fourth Otter accident took place during takeoff; the aircraft landed inverted in three feet of estuary river water off the Duke of York

Bay, Southampton Island, Northwest Territories. The outside air temperature was 10 degrees C and the wind was reported as 5-10 mph. The fifth Otter accident occurred on a lake close to Petawawa in June when lake water was warm. Lifepreservers were deployed successfully in this case and reported to have been worn in the second Otter accident only.

Finally included under this heading as previously discussed is the crew of the Tutor which ejected into 10.6 degrees C lake water in Saskatchewan, boarded their one-man liferafts, and awaited rescue 54 minutes later. The air temperature was also 10.6 degrees Centigrade, the lake was calm, and waves were reported as 1-3 feet in height.

HYPOTHERMIA

There have been four cases of hypothermia (three sea water and one fresh water immersion); in two cases, there was a requirement to wear immersion suits but one crew had elected not to do so. There were no cases where hypothermia was the cause of death.

The first case was one of true clinical hypothermia and also the only one where active treatment by rewarming in hot water has been necessary. This occurred in the case of a pilot of a Starfighter who ejected off the coast of Denmark into sea water at 16 degrees C. His temperature (site not identified) was 34.7 degrees C on rescue and after 45 minutes active rewarming, (technique again not identified) was 37.5 degrees C. He was not wearing an immersion suit (not required) and was rescued by helicopter 23 minutes after immersion. Most important to note is that the pilot lost his single man liferaft (which will be discussed later in this report). Being a strong swimmer, he made attempts to swim to shore and as a result lost a considerable amount of body heat. In only the second of these three cases, a Sea King 30 miles southeast of Shearwater were immersion suits worn, (which incidentally all leaked several litres of water - the sea water was 2.2 degrees C). All the crew were very cold and had numb hands. The third case was a Voodoo on a training air intercept mission which pitched up; both pilot and navigator ejected 150 miles southwest of Portland, Oregon, into 12.5 degrees C water. Neither aircrew had elected to wear immersion suits although in this case there was a requirement to do so. Both crew members were rescued from their respective one-man liferaft one and one-half hours later by a Coastguard helicopter. They were cold and noted that the flare gun was not easy to operate with cold slippery wet gloved hands.

The fourth case was one in which the crew members of a Tutor ejected into 10.6 degrees C water south of Moose Jaw, Saskatchewan. Rescue occurred in 54 minutes; both crew were cold and one member was clinically hypothermic with a rectal temperature of 36 degrees C. No active rewarming was considered necessary.

There were four other accidents in which there was mention in the Board of "cold hands", or "feeling cold", "wet and miserable". These could be considered as potential cases of hypothermia if rescue had not been effected so quickly.

The first case involved one survivor of a Sea King at night in 21 degrees C sea water 300 miles southeast of Halifax, following an engine failure during an anti-submarine warfare exercise off a destroyer. (The

l. "allow the wearer to position his head as close as possible to the canopy (i.e. offset from head to outermost point of the assembly no greater than 4.0 cm)."

The increase in profile at all locations for all helmets exceeds 4.0 cm and, thus, none of the helmets meets this requirement. The HGU 33PD and DH 200D had the least vertical and longitudinal profiles and, along with the HGU 33PS, were reportedly the best in terms of helmet/canopy contact.

m. "consist of a minimum number of parts, with provision for retention in place of all parts during planned use."

No extraneous parts were noted among the contending helmets. The DH 41-4 helmets clearly had the greatest number of parts, while the remaining helmets had essentially the same number of parts. The only helmet component noted as being poorly retained in use was the visor knob retention screw of the EEK 4AP. Exclusion of the DH 41-4 helmets and those equipped with the EEK 4AP visor leaves only the DH 200D and HGU 33PD meeting this requirement.

The MBU 12P has significantly fewer parts than the other oxygen masks due to the permanent bonding of the face seal to the exoskeleton, the use of a single combination inhalation/exhalation valve and the lack of an antisuffocation valve. No mask components were reported lost in use. The MBU 12P oxygen mask therefore best meets this requirement.

n. "shall have no dissimilar metals in contact."

No evidence of dissimilar metals in contact was seen in any of the test equipment.

p. "shall be compatible with cockpit structures, controls and displays, aircrew protective equipment and aircrew spectacles."

Aircrew assessed the HGU 33PD, DH 186 and DH 200S to be the helmets most compatible with aircrew equipment. The major compatibility problem was related to aircrew spectacles, particularly when worn under the visor of the HGU 33PS. The USN modified their aircrew spectacles to allow them to interface with this visor (27). The only reported incompatibility with cockpit structures was scratching of aircraft canopies by the EEK 4AP visor knob retention screw (DH 186, DH 200S, HGU 33PS helmets). No mask related incompatibilities were reported. Hence, the HGU 33PD with any of the oxygen masks best meets the requirement of compatibility with aircraft and aircrew equipment.

q. "shall be compatible with helmet equipment such as flash blindness protection devices, visual target acquisiton systems (VTAS) and heads-up displays."

The compatibility of the EEU 2AP thermal flash blindness protection device with each of the candidate helmets and masks was investigated in a separate evaluation. The device is incompatible with all of the single visor equipped helmets. Some minor modifications to the attachment device would be required for use with the DH 41-4D helmet and with the A13A oxygen mask. The other helmets (DH 200D and HGU 33PD) and masks (P/Q, W and MBU 12P) were compatible with this device.

The USN VTAS II was designed for use with the PRK 37P shell and is

therefore compatible with the DH 200, DH 186 and HGU 33P helmets. Evaluation of interference with the heads up displays was not conducted, but such interference is not anticipated. The dual visor equipped PRK 37P derivative helmets, mated with the W, P/Q or MBU 12P oxygen masks, are therefore considered to meet this requirement.

r. "shall be non-toxic."

The only toxic materials identified in this evaluation were the components used to form the foam liner of the V-Tec Custom Fit Interliner of the HGU 33P helmet. The polymeric isocyanates used are not hazardous after or, with adequate ventilation, during the foaming process.

s. "provide impact protection to the maximum area possible while not restricting the complete range of motion of the wearer's head and neck."

The helmet reported by aircrew to be least restrictive of head mobility was the HGU 33PS. This helmet equipped with the TPL also provided the best impact protection overall to the wearer. Further, the PRK 37P shell extends lower at the sides of the head than do the shells of the DH 41-4 helmets. It is concluded that the HGU 33PS best meets this requirement.

t. "provide eye protection from sunlight or other light sources to an acceptable level and that such device shall mate with the contour of the oxygen mask, etc, to avoid wearer distraction from edge lighting."

The neutral tinted visors provided for all of the helmets were manufactured to Mil V-85374 (AS) and provide acceptable eye protection from sunlight. There are foreseeable light hazards (intra beam laser viewing, nuclear flash) for which these visors are not designed to protect. Compatibility of helmets with nuclear flash blindness protection devices has been discussed. The USN currently uses a visor which is effective in absorbing the light from a neodymium laser. This visor is available for use with the PRU 36P, and other contours could be procured.

Edge lighting due to gaps between the oxygen mask and a tinted visor was a frequent occurence during the operational evaluation. The problem is that the relative position of the oxygen mask and helmet to the visor varies between individual aircrew. Furthermore, the contour of the upper surface of the oxygen masks varies with distance from the face. It is likely, therefore, that custom trimming will be required to eliminate edge lighting. Trimming is only effective if there is enough visor to reach the mask, which is not the case for many aircrew using the CF1 visor of the DH 41-4S helmet. All of the visors, except the CF1, are considered to satisfy this requirement.

u. "provide maximum wearer comfort for the duration of normal missions ie, up to two hours."

Aircrew consider the HGU 33PD to be the most generally comfortable helmet, while the mean of the aircrew rating of all comfort related qualities indicates that the DH 200S and the HGU 33PD were preferred overall. The pilots that assessed the TPL considered its comfort to be equal to that of the Snake or V-Tec liners. The HGU 33PD equipped with either V-Tec or TPL liners are therefore considered to provide maximum wearer comfort.

The comfort of the MBU 12P and P/Q oxygen masks was preferred over that

of the W and A13A masks during the operational evaluation. However, the aircrew participating in the longer term maintenance evaluation considered the W mask to be the most comfortable and disliked the MBU 12P. Only the A13A was disliked by both groups and, hence is considered to fail to meet this requirement.

v. "be capable of being donned and doffed with minimum difficulty while wearing gloves."

The DH 41-4 and DH 200 helmets, both dual and single visor, were considered easy to donn/doff with gloved hands by more than 80% of the respondents. They are therefore considered to be capable of being donned and doffed with minimum difficulty. The W and P/Q masks were clearly considered the easiest to donn/doff, although all masks except the A13A were reported acceptable by greater than 80% of the respondents. Thus, all masks except the A13A are considered acceptable.

w. "be of a size range that will fit 3rd through 98th percentile aircrew."

As no current aircrew anthropometric data are available, this evaluation was conducted during the fitting of the assemblies to aircrew throughout the trials. While all of the fifty-six subjects were successfully fitted the DH 41-4 and DH 200 helmets, one subject could not be fitted with the DH 186 or HGU 33P. This subject has approximately a 98 percentile head. All helmets are therefore considered to meet this standard. All subjects could be fitted with each oxygen mask type except the MBU 12P which is considered not to meet this criteria.

x. "minimum maintenance to ensure proper operation, fit, retention and acceptable overall appearance."

The EEK 4AP (single) visor and W oxygen mask developed serious maintenance deficiencies pertaining to proper operation during the trial. Visor deficiencies such as split covers, sheared retaining screws and canopy scratching have not been resolved, and resolution seems unlikely. By contrast, installation of a PTFE sleeve over the harness guides of the W mask protects against wire cover fraying, improved swaging of the wire to the yoke harness eliminates fatigue failure and a slight increase in the thickness of the reflected seal at the bridge of the nose prevents it from tearing. Fit retention was a problem only with the DH 41-4. The wandering earcups of the DH 200 and HGU 33P are considered to be an insignificant problem which could be resolved by installation of earcup securing cords similar to those installed on the USAF HGU 26P. The only appearance problem during the trial was the DH 186 inner shell paint flaking. Thus the EEK 4AP visor and DH 41-4 and DH 186 helmets do not satisfy the maintenance requirement.

y. "be able to withstand one year's normal opoerations use."

Aircrew assessment of ruggedness shows universal acceptance of the dual visor equipped helmets, supported by the results of the maintenance evaluation over an eleven month period. It is concluded that a helmet equipped with either the PRU 36P or CF2 dual visor system will withstand the rigors of use and abuse by aircrew for at least one year.

5.2 Equipment Selection

5.2.1 Helmet

Aircrew indicated a clear preference for the PRK 37P shell equipped with any of the TPL, V-Tec or Snake liners. From a protective standpoint, the PRK 37P shell and TPL fitted with the integrated chin/nape strap is the best. This helmet would offer the best impact and hearing protection, greatest stability, least profile, greatest protected area, and best retention of the contact style helmets. The TPL offers greater flexibility in maintenance, while the shell has no identified maintenance implications. Hence, the only significant drawback of the HGU 33P is that the helmet shell does not allow adequate range of earcup position, and extension of the shell will alleviate this problem.

5.2.2 Visor

None of the visors provides both adequate protection and ease of operation. Only the EEK 4AP or PRU 36P may be fitted to the best helmet. The EEK 4AP would give the least centre of gravity offset and weight but is difficult to use and has maintenance deficiencies. Further, DFS has indicated (28) that only the protection provided by a dual visor is acceptable. The visual field restriction by the PRU 36P may be addressed by a cutaway of the leading edge of the visor cover. The weight, centre of gravity and profile deficiencies of this assembly should be rectified. The only selection that may be made at this time is the PRU 36P, although research should be conducted to address its known deficiencies.

5.2.3 Oxygen Mask

It is difficult to discern the aircrew preference between the W, P/Q and MBU 12P oxygen masks. The A13A with bayonet suspension was disliked by pilots of both the operational and maintenance evaluations generally due to the long-stemmed bayonet fitting. With short-stemmed bayonet suspension, this assembly improves the critical shortcomings of the A13A mask with the pate suspension. There is a protection dilema in that the P/Q and W offer superior physiological performance and the poorest windblast performance, while the MBU 12P is the opposite. Since masks must provide correct breathing gases throughout flight and retention performance is only significant during ejection, the P/Q and W masks are considered superior. They are also logistically better with only two sizes vice four for the MBU 12/P. The W mask physiological performance is superior to that of the P/Q (11), the modular design of the W simplifies maintenance and the natural rubber of the P/Q face seal is susceptible to deterioration. Hence, the W is considered to be the best mask selection, providing maintenance deficiences are corrected by incorporating a PTFE sleeve over the harness guides, improving swaging of the wire-to-yoke harness and using a thicker reflected seal.

6. CONCLUSIONS and RECOMMENDATIONS

The best helmet/mask system for use in CF ACM aircraft is an extended PRK 37P shell, TPL, integrated chin/nape strap, cutaway PRU 36P (dual) visor and modified W oxygen mask.

The short-stemmed bayonet suspension improves the critical shortcomings of the A13A oxygen mask with pate suspension.

REFERENCES

1. DEACON, P.W., Unsatisfactory Condition Report - Flying Helmet, Jet Aircrew, UCR No. Y2455/8057, 02 June 1978.

2. TASK DESCRIPTION SHEET, NFA Life Support: Helmet and Head Protection, 20 Sep 78.

3. LAZOWSKI, J.C., Survey of High Performance Aircrew Opinion Relative to the DH 41-2 Aircrew Helmet and A13A Oxygen Mask With Pate Suspension, DCIEM Technical Memorandum 3614F-10-6(MLSD), 11 Feb 80.

4. LAZOWSKI, J.C., Aircrew Ranking of Helmet Design and Performance Characteristics, DCIEM Technical Memorandum 3614F-10-6(MLSD), 18 Feb 80.

5. CF Aircrew DH 41-2 Helmet and A13A Mask, Memorandum 18475-102(DAES 4-3), 13 December 1979.

6. LAZOWSKI, J.C., Design and Testing of Further Prototype Modifications to the DH 41-2 Aircrew Helmet for Wear in Air Combat Manoeuvering, DCIEM Technical Memorandum 3614F-10-6(MLSD), 28 Jan 81.

7. TASK DESCRIPTION SHEET, Lightweight Aircrew Helmet (Revision One), 10 Apr Apr 81.

8. CRISPIN, R.E., Operational Evaluation of Lightweight Aircrew Helmets, OPNAV Report 3960-1Z, 9 Feb 1977.

9. COWGILL, D.W., J.A. Van Haastert, W.J. Sears and R.C. Stork Evaluation of the Sierra Engineering Co. Lightweight Helmet Report SAM-TR-78-13, June 1978.

10. Aircrew Helmet User Trial Support - Final Report, Msg AETE A/CO 672 212135Z Jun 82.

11. ERNSTING, J., Comparative Assessment of Impedance to Breathing Imposed by Certain Combinations of USAF, USN and RAF Pressure Demand Masks and Diluter Demand Oxygen Regulators, Unpublished, 30 Apr 81.

12. The Minimum Physiological Design Requirements for Aircrew Breathing Systems, ASCC Advisory Publication 61/3A, 20 Sep 79.

13. MK 4A Flying Helmet General Requirements and Capabilities, Helmets Ltd., July 1980.

14. LAZOWSKI, J.C., User Trial DH 41-21/DH 41-22 High Performance Aircrew Helmet, DCIEM Technical Memorandum 3614F-10(MLSD), 27 Jan 81.

15. Military Specification MIL-M-85047(AS) 1978 Helmet Assembly, HGU 34/P.

16. CLARKE, D.P.J., and S.J. Lederman. Acoustic Properties of Headgear: XXVI, The Gentex Corp. Helmet Model DH 41-2 Hearing Protector with Three Sizes of Earcups, DRET Technical Memorandum No. 678.

17. NEWMAN, J.A. On the Use of the Head Injury Criterion (HIC) in Protective Headgear Evaluation, Mechanical Engineering of the University of Ottawa.

18. CRUCHLEY, J.I., Acoustic Properties of Four High Performance Aircrew Helmets, DCIEM Report - in preparation.

19. FORSHAW, S.E., Hearing Loss Risk in Canadian Forces Aircraft. DCIEM Report No. 883, Sep 1982.

20. LAZOWSKI, J.C., Calculated Performance of the DCIEM Subsonic Windblast Facility. DCIEM Report - in preparation.

21. Human Protective Capability of Various Helmet Design Features - Centre of Mass, Mass Moment of Inertia, Dayton T. Brown Inc., Engineering Report No. 9763, 15 Jan 68.

22. Helmet/Oxygen Mask Trial Phase I, Msg 434 Squadron OPS 113 111630Z Sep 81.

23. FORSHAW, S.E., Guide to Noise Hazard Evaluation, DRET Review Paper No. 771, November 1970.

24. MICHAS, R.D., J.A.G. Porlier and R.C. Rud, Development and Testing of a New Partial Pressure Jerkin. DCIEM Report No. 81-R-39, Nov 81.

25. ERNSTING, J., Letter on ASCC ADV PUB 61/3A, IAM/1041/B/26, 16 Oct 1980.

26. SLOBODNIK, B.A., SPH-4 Helmet Damage and Head Injury Correlation, Aviation Space Environmental Medicine 50(2); 139-146, 1979.

27. CHISUNA, G.T., Integration of Aviators Eye Protection and Visual Aids, AGARD CP-191, October 1976.

28. AIRCREW HELMET, NDHQ/DFS Letter 14220-102(DFS 2), 20 Jan 81

ANNEX A

A. DESCRIPTION OF EQUIPMENT

A.1 Helmets and Visors

Within the USAF, three helmets were designed to fulfil the requirement of air combat pilots. The design of each was initiated by a different agency. First, the USAF School of Aerospace Medicine in conjunction with Sierra Engineering Corporation undertook the design of an entirely new aircrew helmet. This helmet, generally known as the Sierra Lightweight Aircrew Helmet, was the result of an extensive research and development program (9). It embodied several novel ideas including an integrated nape-chin strap, a lift-spoiling visor cover, flattened helmet sides and a "rapid action" visor locking device. This development was terminated in 1978 after flight trials in which deficiencies in comfort due to both inner contact liner molding problems and the position of the chin strap were reported. This helmet was not available for evaluation.

The HGU-48/P, the second of the USAF helmets, was developed by the Life Support Systems Programme Office as an interim modification to the HGU 26/P. This helmet was designed to reduce the profile and weight of the HGU-26/P as well as improve the centre of gravity location. The helmet is a standard HGU-26/P with the dual visor assembly removed. Visual and facial protection is provided by a single visor which is attached to an elastic strap on each side, in turn connected to a pull-the-dot fastener on the helmet shell. The visor is protected from the shell by leather patches and is restrained from backward movement past the lateral centerline of the helmet by two leather covered foam blocks. These are mounted on the shell on each side of the central longitudinal plane. It was decided not to evaluate this helmet since it was solely an interim development.

In response to a Tactical Air Command request, the Gentex Corporation had developed a third USAF helmet, the HGU-53/P. It incorporates a single exposed-hinge visor similar to that of the pre-1970 DH 41-2. Lightweight materials are used in the shell to decrease weight and the shell contours have been modified to reduce the effect of windblast. This helmet was still in the early stages of development and was not available for evaluation.

In the early seventies, the USN undertook the development of a new series of helmets. The goal of this development was to utilize as few helmet shells and liner systems as possible to accommodate all Naval aviators. The flight trial of these helmets was successfully completed and they are now in service. The basic helmets of this family, designated the HGU-33P and HGU-34P, are being flown in the F-14 and F-18 aircraft. They are both contact helmets incorporating the PRK 37P shell, their sole difference being the liner. The HGU-33/P incorporates a custom fit liner while the HGU-34/P makes use of a pad-fit system. Both have a single visor system (EEK 4AP) protected by a polycarbonate visor cover. There are four visor types available - gradient, clear, neutral tinted and "high acuity" yellow. These visors may be easily interchanged on the ground by the pilot. The PRU 36P dual visor assembly is also compatible with these helmets and provides the pilot with the clear and neutral or gradient tinted visors. Originally the HGU 33/P was fitted by means of the USAF form fit system, but this liner has recently been replaced by the V-Tec Custom Fit Interliner (TM). This device simplifies custom fitting of a helmet because no ancillary equipment beyond a very simple fitting jig is required. This helmet was available and was ordered for evaluation. The HGU 34/P causes more discomfort

than the HGU 33/P helmet (8) and was not included. Near the conclusion of the maintenance evaluation a third helmet lining system became available that was designed for the HGU 33/P. Fitting of this system is accomplished through molding of a Thermal Plastic Liner (TPL). Impact protection is provided by a rigid expanded polystyrene interliner between the helmet shell and the TPL. Four of these liners were available and test flown at the conclusion of the maintenance evaluation.

The USN has also designed a more advanced helmet that, if successful, will replace the HGU-33/P. Designated the HGU-35/P, its major innovation is the routing of the oxygen delivery hose through the back of the helmet. This improves the location of the centre of gravity of the helmet, resulting in less torque about the head during exposure to gravitational forces. This helmet shell was manufactured from an epoxy based composite of Kevlar and graphite. Kevlar is a light weight, high strength material and graphite is a high stiffness fibre. The helmet is custom fit by means of a V-Tec interliner. It was postulated that this helmet would cause poor seat/man separation because of the routing of the oxygen delivery hose. However, no interference was experienced during an actual seat/man separation trial carried out at the Aerospace Engineering Test Establishment (AETE) (10). A second major concern was the extremely high breathing resistance of the assembly. This resistance was 1.7 to 2.0 times that imposed by the A13A mask when used with the same oxygen delivery system (11) and well beyond the recommended total resistance (12). Although this helmet was ordered, it was withheld from the trials due to the high breathing resistance.

The RAF has recently developed the MK 4 Flying Helmet, which is a rigid shell suspension helmet incorporating a dual visor system. The reported performance of this assembly has indicated that it would provide adequate protection for high performance aviators. However, it was considerably heavier (19.6 N) than the target of 14.7 N (13). Due to production problems, efforts to borrow this item through a Test Project Agreement (TPA) were unsuccessful, so the helmet could not be evaluated.

The CF, in the past two years, developed three new helmets for high performance aircraft. The DH-186 is a suspension helmet which incorporates a novel fitting technique. The helmet shell may be removed to expose the suspension straps, which may then be adjusted and fixed at the correct length. The shell construction is graphite and Kevlar, similar to that of the HGU-35/P, and its contour conforms to that of the PRK 37P. The shell is lined with more than one-half inch of expanded polystyrene (styrofoam) to provide additional energy attenuation. This helmet employs a single visor system (EEK 4AP) only and was evaluated.

The second CF helmet was the DH-200 or "Snake", which used a modified version of the PRK 37P helmet shell and a particle liner manufactured at DCIEM. This particle liner is in full contact with the protected portions of the head. The liner consists of a mesh tube filled with small polystyrene beads and coiled about a perforated leather comfort liner. This helmet does not require individual fitting. It incorporates an integrated nape-chin strap similar to that of the Sierra light weight helmet. The helmet was originally designed to be fitted with a single visor system (EEK 4AP) for optimum weight, profile and centre of gravity. The option of a dual visor system (PRU 36P) was later added for additional facial protection. This helmet, including both visor systems, was evaluated.

The third CF helmet was the interim modification to the DH 41-2 aircrew

helmet (6). There were two versions, both designated DH 41-4, each of which allowed visual field beyond that of the DH 41-2. One version incorporated a single visor (CF1), the other a dual visor (CF2). They were intended to resolve only the more critical shortcomings of the DH 41-2, but it was thought that either might prove suitable as the long-term solution.

A.2 Oxygen Masks

The modified MBU 3/P mask suspension, which was used in place of the Pate suspension on the A13A mask used by CF aircrew, is a lightweight plastic mask holder attached to the helmet by bayonet fittings.

The MBU 12/P mask has a low profile and is attached to the helmet by bayonet connectors. A combination inhalation/exhalation valve is used, rather than the separate valves that are found in the other masks considered. The face seal is bonded directly to the body of the mask rather than having a soft inner mask supported by a rigid exoskeleton. Although this bonding caused production delays, the mask was available and evaluated.

The P/Q mask is supported by the sulcus of the chin and, hence, is very stable under "G". Consisting of a natural rubber inner mask supported by a rigid exoskeleton, it will accept high breathing pressure. The mask includes a simple mechanism that allows the wearer to quickly increase the tightness of the mask on his face ("toggle down") - a feature used after sudden cabin depressurization or during air combat. The P/Q mask is attached to the helmet by an adjustable hook and chain assembly. This mask has many components in common with the AR-5 CW respirator, which has been recommended for use in the CF for the CF-104 and CH-136.

The W mask (developed from the P/Q mask) features a silicon inner mask, a redesigned exoskeleton, a light weight microphone, modular construction, improved helmet/mask connectors and a built-in anti-suffocation valve. The new connectors are extremely light and provide less potential for injury than the hook and chain of the P/Q mask. Although this item was still in the final prototype stage, it was available for evaluation.

B. TRIAL DESIGN FOR OPERATIONAL EVALUATION

Forty weeks were available between the earliest practical trial initiation date and the latest decision date that would ensure procurement during fiscal year 1982 - 1983. The final twenty-five weeks of that period were required to complete the laboratory evaluation, data reduction and reports. Thus it was necessary to limit the trial duration to fifteen weeks.

There were twenty-eight possible helmet/oxygen mask combinations. A minimum of twelve working days were considered necessary for aircrew to assess each combination, thus requiring a trial duration that would greatly exceed the time available. Participants therefore evaluated only one visor configuration and one of the four oxygen mask types during the main part of the operational evaluation. Questionnaires are attached as an Appendix.

Forty-one of the aircrew each conducted a series of up to four individual helmet assessments. To evaluate the different oxygen mask types, the participants were divided into three groups each of similar average age, height and jet aircraft flying experience (Table B1). The first group, designated Alpha, assessed both the P/Q and "W" masks because of their similarity and the limited number of "W" masks available.

Table B1 - Aircrew Group Data

Group	Mask	Aircrew	Age (Yrs.)		Height (cm)		Flying Hours	
			m	s	m	s	m	s
Alpha	PQ,W	14	34.1	5.1	179	7	2790	1440
Beta	MBU 12P	13	34.7	5.3	180	5	3140	1450
Gamma	A13A	14	34.7	4.6	178	5	3010	990

Notes: m = mean value
s = standard deviation

In order to facilitate helmet exchanges, the groups were further divided into subgroups, each with (three or four) members (Table B2). Members of a subgroup required the same helmet size. In each group, three subgroups wore medium helmets and one subgroup wore large helmets. Subgroup members were issued one of the three or four helmets, as indicated in Table B2. The members of a subgroup rotated the helmets among themselves after each twelve working day cycle. The ordering of the helmets in Table B2 indicates the order of rotation.

Table B2 - Equipment Disposition Among Aircrew

Group	Subgroup	Size	Helmets*	Mask	Visor
Alpha	1	Medium	1,3,4,2	RAF "W"	Single
	2	Medium	1,4,2,3	RAF P/Q	Single
	3	Medium	2,4,3	RAF P/Q	Dual
	4	Large	1,4,2	RAF P/Q	Single
Beta	1	Medium	1,4,3	MBU 12/P	Single
	2	Medium	1,2,3	MBU 12/P	Single
	3	Medium	1,2,4,3	MBU 12/P	Dual **
	4	Large	2,4,3	MBU 12/P	Single
Gamma	1	Medium	1,2,3,4	A13A	Single
	2	Medium	1,3,2	A13A	Single
	3	Medium	1,3,4,2	A13A	Dual **
	4	Large	1,4,3	A13A	Dual **

* Key: 1 - DH 186 3 - HGU 33/P
2 - DH 200 4 - DH 41-4
** Single Visor for DH 186 Helmet

The imbalance in subgroup sizes was the result of the withdrawal of seven scheduled participants (due to posting, temporary duty, etc.). In order to utilize equipment resources as effectively as possible, six aircrew of 434 Sqn evaluated one helmet and oxygen mask type while deployed to Norway. The remaining vacancy was filled by the trial director who evaluated two helmets.

There are twelve possible orders of consecutive helmet assessment. Each order occured an average of seven times, with the following significant deviations due to the above imbalance and the decision of some aircrew not to wear particular assemblies (due to perceived safety hazard or assembly considered entirely unsuitable):

a. HGU 33P followed by DH 186 - 11 occurrences
b. DH 41-4 followed by HGU 33P - 12 occurrences
c. DH 41-4 followed by DH 186 - 2 occurrences

Two steps were taken to assess the differences between single and dual visor assemblies. First, one subgroup wearing medium helmets in each group used dual visors throughout the trial (except with the DH 186), as did one of the three subgroups wearing large helmets. Second, some participants assessed single vs dual visors directly by changing the visor configuration after the last helmet evaluation for an additional twelve day evaluation period.

A total of 182 helmet assessments were conducted, for which 144 reports were submitted. The distribution of reported assessments by helmet/mask combination is shown in Table B3. The distribution of the number of reports by participants is shown in Table B4. The flying time per assessment ranged widely from 1 to 45 hours with a mean of 14.6.

Table B3 - Reported Assessments for Helmet/Mask Combinations

Helmet*	MBU 12/P	P/Q, "W"	A13A	Total
DH 186S	9	10	11	30
DH 200S	7	9	8	24
HGU 33PS	8	8	9	25
DH 41-4S	6	8	6	20
DH 200D	6	4	5	15
HGU 33PD	7	5	5	17
DH 41-4D	5	4	4	13
Total	48	48	48	144

* Suffix S = single visor; D = dual visor

Table B4 - Number of Helmet Reports by Participants

Assessments Returned (per Aircrew)	No. of Aircrew		Total Assessments
1	7		7
2	7		14
3	16		48
4	15		60
5	3		15
		Total	144

Twenty-nine aircrew participated in the final 12-day evaluation comparing the dual and single visor systems. Twenty-six visor questionnaires were submitted, but background data of the reporting group such as helmet and mask types used and flying times involved were not fully documented. Twenty-six oxygen mask assessments were also submitted by this group - seven of the P/Q, three "W", eight MBU-12/P and eight A13A. Mean mask exposure times were 54, 50, 46 and 43 hours, respectively, with standard deviations of approximately 19 hours.

APPENDIX B1

HELMET QUESTIONNAIRE

1. Which aircraft have you flown this cycle?

   a. CF-104   b. CF-5   c. Other

2. Which helmet did you wear this cycle?

   a. HGU-33/P   b. DH-186   c. DH 41-4   d. DH-200

   equipped with 1 or 2 visors

3. How many hours have you flown this cycle? ________

4. Which oxygen mask are you wearing for the trial?

   a. P/Q   b. W   c. MBU-12/P   d. A13A

5. Which helmets have you worn thus far in this trial?

   a. HGU-33/P   b. DH-186   c. DH 41-4   d. DH 200

6. How would you rank order the helmets you have worn to this point?

   1. ________________
   2. ________________
   3. ________________
   4. ________________

7. Did the helmet allow effective and acceptable communications?

   Never   Seldom   Sometimes   Often   Always

8. Did you find the actuation of the visor(s) difficult?

   Never   Seldom   Sometimes   Often   Always

9. Did you find the hearing protection provided by the helmet acceptable?

   Never   Seldom   Sometimes   Often   Always

10. Did the visor(s) ever move from the position in which you had set it/them?

    Never   Seldom   Sometimes   Often   Always

11. Did the helmet remain stationary on your head during flight?

    Never   Seldom   Sometimes   Often   Always

12. Did the helmet restrict your field of view?

    Never   Seldom   Sometimes   Often   Always

13. Did the helmet allow you to move your head within the cockpit as necessary?

    Never   Seldom   Sometimes   Often   Always

14. Did the helmet contact the canopy when you had the seat adjusted to the position you prefer?

Never Seldom Sometimes Often Always

15. Did the helmet integrate well with other articles of aircrew equipment or sun glasses? Yes No

If no, please specify ______________________________

16. Did the helmet have any sharp edges or protrusions that you feel could be injurious? Yes No

If yes, please specify ______________________________

17. Were there any gaps between the oxygen mask and the visor(s)? Yes No

If yes, were these distracting? Yes No

18. Was the helmet easy to donn and doff with gloved hands? Yes No

If no, what actions did you find difficult? ______________________________

19. Did the helmet cause you any discomfort? Yes No

If yes, please describe ______________________________

20. Is the colour of the helmet acceptable? Yes No

If no, what colour scheme would you prefer and why? ______________________________

21. Did you find this helmet hot to wear? Yes No

If yes, under what conditions? ______________________________

22. Are you satisfied with the ruggedness of this helmet? Yes No

If no, why? ______________________________

23. Was the length of time involved in fitting the helmet acceptable? Yes No

How long did the fitting process take? ______ ______ hours

24. Did the earcups feel uncomfortable? Yes No

25. Do you feel that a satisfactory fit was achieved? Yes No

26. Was the weight of the helmet acceptable? Yes No

27. Did you find any difficulty in forming an opinion of the helmet in the time allotted? Yes No

If yes, please explain. ______________________________

28. Do you feel this helmet is an improvement over the CH DH 41-2? Yes No

29. In light of your experience, what changes would you make to this helmet?

____

OXYGEN MASK QUESTIONNAIRE

1. Which aircraft have you flown during the trial?

   a. CF-104 b. CF-5 c. Other ________

2. Which mask did you wear?

   a. P/Q b. W c. MBU-12/P d. A13A

3. How many hours have you flown during the trial, so far? ________ hours

4. Did the mask provide any restrictions to breathing?

   Never Not Usually Sometimes Often Always

5. Did the mask make a good seal with your face?

   Never Not Usually Sometimes Often Always

6. Did the mask microphone contribute to communication difficulties?

   Never Not Usually Sometimes Often Always

7. Did the mask contours mate well with various visors?

   Never Not Usually Sometimes Often Always

8. Did the mask move about on your face during flight?

   Never Not Usually Sometimes Often Always

9. Was the mask easy to donn and doff?

   Never Not Usually Sometimes Often Always

10. Did the mask interfere with your field of view?

    Never Not Usually Sometimes Often Always

11. Did you find this mask comfortable? Yes No

    If no, why? ____

    ____

12. Did you find this mask acceptable? Yes No

13. Was the means by which this mask was attached to the helmet acceptable? Yes No

    If no, how would you improve it? ______________________________

    ____

14. Please use the space below to make any additional comments on this particular piece of equipment. For example, changes you would suggest, particular merits or deficiencies of the mask, etc.

____

SINGLE VS DUAL VISOR QUESTIONNAIRE

1. Considering both the protective qualities and the effect upon profile, field of vision, weight and centre of gravity location, please explain which system you would prefer and why.

____

ANNEX C

C. LABORATORY TEST METHODS

C.1 Impact Protection

Three medium sized helmets of each type were impacted once at the crown, rear, side and front. As many as three additional helmets were tested when large data variations were encountered. The helmets tested were complete including visor systems, communication equipment and oxygen mask connectors. No environmental conditioning was done.

Helmet energy absorption characteristics were determined by means of monorail-guided free fall on to a flat 13.3 cm diameter steel anvil. The helmet was mounted on a supported, medium sized magnesium headform. The total falling weight without helmet was 49.4 N. A single uniaxial piezoelectric accelerometer was mounted at the centre of the headform, oriented along the impact axis. A photoelectric sensing system determined impact and rebound velocities of the helmeted headform at a position typically 0.50 cm above the point of impact. The drop height was varied to compensate for variations in helmet weight in order to control impact kinetic energy. The mean value was 89.41 J, with a standard deviation of 0.84 J.

A transient recorder performed real time, high speed, multi-channel analog-to-digital (A/D) data conversion and storage. The A/D converter resolution was one part in 1024 of its dynamic range. The sampling frequency was 10,000 Hz. The total recorded history was about 41 milliseconds. A well defined high onset rate pulse was obtained by severely overdriving a high gain amplifier and was used to trigger the recorder.

The raw data were transferred to a PDP 11/34 computer and converted to engineering units using the accelerometer sensitivity and A/D converter parameters. The acceleration pulse was integrated to yield velocity and displacement profiles. The Gadd Severity Index (GSI) and Head Injury Criteria (HIC) were determined from impacts of median peak acceleration for purposes of helmet comparison but not for predicting head injury potential. A detailed discussion of these indices is provided by Newman (17).

C.2 Penetration Resistance

The penetration resistance of the candidate helmets was not determined as this test has not been shown to relate directly to a hazard within the aviation environment.

C.3 Hearing Protection

The real ear threshold shift method was employed to determine the aural protection offered by each of the candidate helmets, in accordance with Acoustical Society of America (ASA) Standard 1-1975 - "Method for the Measurement of Real-Ear Protection of Hearing Protectors and Physical Attenuation of Ear Muffs". A sound absorbant rather than reverberant room was used. The sound source was a single speaker facing the subject. Each helmet was tested three times on each of ten subjects. This evaluation was reported separately by Cruchley (18). The mean attenuations less one standard deviation (x-s) were used to determine the ISO noise rating numbers in the 'worst case' sonic environments of the CF 5 and CF 104 aircraft (19). These numbers were then translated into maximum permissible exposure times.

C.4 Communications Capability

All of the candidate helmets were equipped with standard CF aircrew telecommunications. Therefore, no testing was required.

C.5 Facial Protection and Retention During Windblast

The facial protection and retention characteristics were assessed by conducting windblasts for each oxygen mask/helmet combination and for the helmet alone. All of the helmets were evaluated with the outer visor deployed. Each configuration was exposed twice to 450 knots (CAS) and twice to 560 knots (CAS) nominal flow velocities. The typical peak dynamic pressures for these tests were 35 and 55 kPa, respectively. Typical blast duration to fifty percent decay was 400 ms. One hundred and forty windblasts were conducted.

The windblast pulse was achieved using a 9-man hypobaric facility. Its satelite and main chambers, which are connected by means of a 23 cm diameter steel duct, were isolated by a paper partition. The main chamber was evacuated while the satelite was open to the atmosphere. The paper partition was mechanically destroyed after the appropriate pressure differential was obtained and stabilized. The air flow through the satelite into the main chamber formed the pulse (20).

Appropriately sized helmets were fitted to a fiftieth percentile anthropomorphic headform. The helmeted headform was oriented such that the relative wind was 0.26 rad (15 deg) below and 0.26 rad to the left of the longitudinal axis. The headform was positioned such that it was as close to the mouth of the windblast duct as possible, but not intersecting the exit plane.

The net displacement of the helmet relative to the head was determined at the lateral centrepoints of the anterior and posterior perimeters of the helmet shell. These position reference points were also used to ensure similar initial placement for all test assemblies. A high speed photographic record of each test was made, but these data were unfortunately uninterpretable due to a camera malfunction.

C.6 Comfort

The operational evaluation satisfied the requirements for this evaluation. The combined operational and maintenance evaluations extended from April through February during which all expected environmental conditions were experienced. The operational roles included air-to air combat, ground support, reconnaissance, training and long-range ferrying.

C.7 Field of Vision

The change in the occluded area of the binocular northern field (upper hemisphere) of vision with respect to the naked head was determined for each helmet. The DH 186 and either the single or dual visor model of each of the other three helmet types were evaluated on each of six subjects. Each dual and each single visor helmet was worn by three of these subjects. The visors were in the stored position for all of these tests.

The visual perimeter was determined using a Bausch and Lomb Model Visual Perimeter. A white target of 3 mm diameter and 9 candelas per square meter luminance was viewed at a distance of 380 mm. Subjects were instructed to move only their eyes to aid in target acquisition or tracking. They were informed of

the direction from which the target would enter the visual field. The perimeter was defined at 0.26 rad (15 deg) intervals. Each defined point was accepted as the midpoint between the inbound target acquisition and outbound target loss points.

The test procedure was designed to offset the variations in individual naked head perimeters. The angular area of each subject's visual field occluded by each helmet was calculated. Each subject's field loss while wearing the DH 186 was taken as unity and the field loss for each of the other helmets worn was expressed as a percentage of that value.

C.8 Centre of Gravity (C of G)

The midsagittal plane centre of gravity was determined for each type of helmet, alone and in combination with each type and practical size of oxygen mask less oxygen delivery hose. The outer visor was deployed in all of the configurations.

The C of G was measured by the method used by Dayton T. Brown Inc. (21), which defines the C of G of the helmeted headform in polar coordinates with origin at the C of G of the naked head and zero axis along the vertical. The helmet/mask is fitted to a balanced headform which allows controlled movement in pitch about the origin. The helmeted headform is rotated until the new C of G lies directly above the origin (metastable equilibrium). The angle of rotation defines the direction of the new C of G with respect to the zero axis. To determine the radial displacement of the helmet/headform C of G, the headform is then rotated 1.57 rad (90 deg) so that gravity acts normally to the arm between the new C of G and the origin. The headform is brought to equilibrium by the addition of weights along the 3.14 rad (180 deg) axis. The displacement of the C of G is defined by the balancing torque and the weight of the helmet assembly.

C.9 Weight

The weights of the individual helmets and oxygen masks were determined using an Accutronic 1000 digital electronic scale accurate to 0.004 N.

C.10 Profile

The maximum lateral, longitudinal and vertical dimensions of three of each helmet type and size mounted on the appropriate headform were determined. The dimension accuracy was 0.05 cm. The offset was the difference between the maximum naked headform and maximum helmeted headform dimensions in each direction.

ANNEX D

D. EVALUATION RESULTS

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D.1 Operational Evaluation

D.1.1 Helmets and Visors

Results obtained from the helmet questionnaires are summarized in Tables D1-D10. Note that a suffix "S" or "D" in helmet designations indicates the single or dual visor configuration, respectively. It was considered to be unnecessary to conduct statistical data analyses in order to determine aircrew preferences and identify obvious problem areas. The data are presented as percentage values of maximum possible scores using three methods as follows:

a. Rank Ordering - The assigned scores ranged from zero (unsuitable) to five (preferred). The scores were examined two ways. The "last response rank ordering" considered the final response only of each participant, and the "average response rank ordering" considered all responses weighted equally.

b. Frequency of Deficiencies - Questions that required responses based upon the observed frequency of deficiencies were scored on a linear scale from one (always deficient) to five (never deficient).

c. Identification of Deficiencies - Questions that would identify a deficiency in a specified area were assigned a score of zero (deficient) or one (not deficient).

Difficulty in forming an opinion of the assessed helmet within the allotted time period was reported by nine of the 144 respondents. Two reports related it to the helmet directly, and both respondents felt that the helmet fitting could have been better. The others cited a lack of ACM or insufficient mission duration, or did not specify the reason.

Table D1 - Helmet Rank Ordering by Aircrew

A. Last Response

Helmet	No. of Ratings	Mean Score
DH 200S	22	92
HGU 33/PS	25	89
HGU 33/PD	15	88
DH 200D	12	82
DH 41-4D	11	62
DH 186	31	57
DH 41-4S	21	50

B. Average Response

Helmet	No. of Ratings	Mean Score
HGU 33/PS	44	92
DH 2000S	43	89
DH 200D	26	83
HGU 33/PD	28	81
DH 186	56	68
DH 41-4D	25	62
DH 41-4S	37	60

Table D2 - Aircrew Assessment of Helmet Comfort

Helmet	No. of Subjects	Percent Respondents Rating Acceptable						Combined Score
		General	Donn	Thermal	Ear	Fit	Weight	
DH 186	30	46	57	76	55	75	83	65
DH 200S	24	68	96	75	50	79	100	78
HGU 33PS	25	68	68	60	56	84	96	72
DH 41-4S	20	45	82	90	65	61	80	71
DH 200D	15	50	86	64	62	64	79	68
HGU 33PD	17	76	73	67	66	88	87	76
DH 41-4D	13	50	100	92	64	73	67	74
ALL	—	58	80	75	60	75	85	72

Table D3 - Aircrew Assessment of Visual Field

Helmet	HGU 33PS	DH 200S	DH 41-4S	DH 200D	HGU 33PD	DH 186	DH 41-4D
Mean Score	89	86	77	72	68	67	62

Table D4 - Aircrew Assessment of Profile

Helmet	Mean Scores		
	Restriction to Head Mobility	Helmet/Canopy Contact	Combined
HGU 33PS	97	84	90
DH 200S	93	83	88
HGU 33PD	87	85	86
DH 41-4S	89	75	82
DH 200D	84	75	80
DH 41-4D	73	70	72
DH 186	74	67	70

Table D5 - Aircrew Assessment of Helmet Stability

Helmet	HGU 33PD	HGU 33PS	DH 200S	DH 200D	DH 186	DH 41-4D	DH 41-4S
Mean Score	98	97	94	93	86	83	77

Table D6 - Aircrew Assessment of Hearing Protection

Helmet	DH 200S	HGU 33PD	HGU 33PS	DH 200D	DH 186	DH 41-4D	DH 41-4S
Mean Score	96	94	93	92	89	88	86

Table D7 - Aircrew Assessment of Communication

Helmet	DH 200S	HGU 33PS	DH 200D	DH 41-4S	DH 186	HGU 33PD	DH 41-4D
Mean Score	95	92	91	89	89	86	80

Table D8 - Aircrew Assessment of Visors

	Mean Scores			
Helmet (Visor)	Actuation	Locking	Mask Interface	Combined
DH 200S (EEK 4AP)	84	92	75	84
HGU 33PS (EEK 4AP)	79	94	72	82
DH 186 (EEK 4AP)	82	92	59	78
DH 200D (PRU 36P)	73	96	64	78
HGU 33P (PRU 36P)	74	92	56	74
DH 41-4D (CF2)	58	95	50	68
DH 41-4S (CF1)	54	94	40	63

Table D9 - Aircrew Assessments of Compatibility, Lethality, Ruggedness and Fitting Time

	Mean Scores				
Helmet	Compatibility	Lethality	Ruggedness	Fitting Time	Combined
HGU 33PD	92	94	100	100	97
DH 200S	87	100	96	100	94
DH 41-4D	82	92	100	100	94
DH 200D	73	92	100	100	91
DH 186	88	90	93	89	90
HGU 33PS	74	100	92	96	87
DH 41-4S	70	90	75	95	80

Table D10 - Percent of Aircrew Preferring Test Helmets Over DH 41-2

	Oxygen Masks			
Helmet	W,P/Q	MBU 12P	A13A	Overall
DH 186	63	38	33	39
DH 200S	89	100	86	91
HGU 33PS	100	86	75	88
DH 41-4S	50	80	20	67
DH 200D	100	100	60	85
HGU 33PD	100	72	60	81
DH 41-4D	50	60	33	55

Aircrew were also asked to indicate where they consider improvements to the helmet assembly are possible. It was clear that each helmet type was, in general, categorized as acceptable or unacceptable. Comments about helmets and visors are summarized as follows:

a. Helmets

(1) DH 200 - The main area of concern was the chin-nape strap combination. It was suggested that the chinstrap portion be lengthened and softened. As well, four respondents requested that the helmet shell be deepened to allow a greater range of earcup placement. This helmet was generally acceptable.

(2) HGU 33/P - The major deficiency mentioned was the fixed length of the nape strap which made the helmet difficult to donn. The chinstrap pad was too stiff. Two of the forty respondents stated that the helmet was thermally uncomfortable. This helmet was also generally acceptable.

(3) DH 186 - Five of the twenty-nine respondents stated that no improvements could be made to render this helmet suitable for their role. The remainder enumerated deficiencies in visual field, profile, weight, stability and donning. Two respondents suggested that a method of securing the earcups to the helmet shell should be investigated.

(4) DH 41-4 - More than a third of the respondents labelled it unsuitable for use and ther were many derogatory comments.

b. Visors

(1) CF - There were no adverse comments about the dual visor, but two respondents requested increased single visor length to reduce the likelihood of gaps above the oxygen mask.

(2) PRU 36P - The predominant suggestion was to reduce the leading edge of the visor cover in order to reduce visual field restrictions.

(3) EEK 4AP - Every portion of this mechanism except for the visor lenses were criticized. The visor turn knob was unacceptable because it separated from the helmet and flying gloves could become caught between it and the visor cover.

The DH 186 was considered unsatisfactory by the users in many of the assessed areas. Most of the deficiencies were directly related to the novel features of this helmet. The helmet was found particularly deficient in comfort related qualities. The intersection of the suspension cross straps at the crown resulted in a high pressure area. The inner shell securing the suspension straps decreased the flexibility of the PRK 37P shell resulting in donning and doffing difficulties. These difficulties were aggravated by the chinstrap which was secured by two (rather than one) directional (pull-the-dot) snap fasteners. The presence of the frontal and occipital fitting pads hindered ventilation decreasing thermal comfort. The universal sizing of the helmets caused aircrew with small heads to be unduly encumbered with respect to profile and visual field. The helmet was frequently considered unacceptably heavy although it was lighter than several helmets which were generally accepted. The fit of the helmet was considered acceptable by three-quarters of the wearers - a better rating than either of the other suspension helmets. The ability to adjust the suspension and earcups directly upon the wearers head may account for this. However, the time required to complete this procedure was considered excessive by 11% of

the respondents.

The DH 41-4 helmets performed comparatively well in only three areas. Both single and dual visor helmets were generally considered easy to donn/doff, caused little thermal discomfort and caused less ear discomfort than most of the others. The flexibility and adjustability of the earcup supports accounts for both the ease of donning and the ear comfort. The thermal comfort is most likely a result of the unhindered ventilation allowed by the suspension design. The problem of discomfort due to the napestrap was the result of a nape strap design change in the early 1970s. The nape strap was rotated downwards to achieve a better grip of the occiput and enhance helmet retention. The leather buckle guard was not realigned to be under the nape buckle, allowing the buckle to contact the wearers neck. The trial and error method of helmet fitting is a task which requires patience on the part of both the aircrew and the technician and without which pressure points inevitably occur in flight. It is noted that while the DH 41-4S was preferred over the DH 41-2 by more than half of the respondents (Table D10), it scored last in the rank ordering (Table D1).

The aircrew showed a clear preference for the contact helmets (DH 200, HGU-33/P) over the suspension helmets (DH 186, DH 41-4) as indicated by the results of both rank ordering (Table D1) and comparison to the DH 41-2 (Table D10). The contact helmets were as a group considered best in all categories except thermal and ear comfort. The complete lack of ventilation about the wearers head inherent in this type of helmet resulted in the poor thermal comfort rating. The ear discomfort was reported to be due to earcup placement. The PRK 37P shell is generally similar in contour and dimension to the APH 6 shell. This shell was originally used with a hard rubber edging which was later replaced by the leather covered foam edgeroll used on the PRK 37P. The addition of the edgeroll eliminated the lower half inch of earcup positioning range.

Two assessments indicating large differences between the DH 200 and HGU 33P were donning/doffing and general comfort. The DH 200 was not difficult to donn or doff while much more difficulty was encountered in the HGU 33P. The nape strap of the HGU 33P may only be adjusted to two positions and is inextensible during donning and doffing restricting spreading of the shell, while the integrated nape-chin strap of the DH 200 does not hinder spreading of the shell and is easily adjusted by the wearer after donning. The general comfort of the DH 200D was markedly less acceptable than that of the HGU 33PD. The DH 200D was reported to be tight. The rigid V-Tec interliner of the HGU 33P may spread the shell outwards more than the soft particle liner of the DH 200 which would tend to conform to the helmet shell. The TPL in the HGU 33/P and DH 200 helmets was unanimously considered equal or superior to the original liners with respect to comfort.

D.1.2 Oxygen Masks

Results obtained from the oxygen mask questionnaires are summarized in Table D11.

Table D11 - Aircrew Assessment of Oxygen Mask Characteristics

Characteristic	Mean Scores MBU 12/P (10 Subjects)	P/Q (9 Subjects)	W (5 Subjects)	A13A (10 Subjects)
Breathing Resistance	75	94	92	88
Facial Seal	72	88	80	72
Microphones	72	88	76	80
Visor Interface	77	88	64	62
Stability	66	84	76	70
Ease of Doning/Doffing	81	87	92	70
Field of Vision	74	92	92	77
Comfort *	88	86	66	44
Acceptability *	86	86	66	44
Helmet Attachment *	100	30	100	26
Combined	79	81	80	63

* Number of subjects decreased by 2.

Aircrew comments about each oxygen mask type and suggested improvements included the following:

a. MBU 12/P - One quarter of the respondents believed this mask should not be worn with the DH 41-4 helmet as the soft cheek flaps did not provide a rigid mounting platform. Half of the respondents reported that the mask was comfortable, emphasizing the weight and the feel of the mask. Interference with vision was reported to occur during start-up when the mask hung from one attachment point and obscured the enunciator panel. The suspension straps also interfered with vision in flight. Comments received in the maintenance evaluation message report (22) are as follows:

"Extremely uncomfortable mask - larger inner seal interfered with mouth movement. Hot spot on bridge of nose, air leakage into eyes. Microphone unreadable and proved to be a flight safety hazard. Insufficient adjustments for mask. When mask disconnected it obstructed vision on one side of cockpit. Unable to fit three pilots with mask due to facial structure. Use of mask discontinued due to flight safety."

b. P/Q - Positive comments focused upon its stability under "G" and toggle system of rapid tightening. However, the suspension system of this mask, particularly the hook and chain portion, was considered to be unsuitable by the majority of respondents. Maintenance evaluation message report comments include:

"Some pressure points in nose area for those people with large noses. Chain system kept getting tangled and in one case resulted in a cut to the pilot's face. Chains were distracting possibly due to coloration. Microphone very poor - garbled and incomprehensive (sic)."

c. "W" - The three operational evaluation respondents submitted three differently slanted comments. One emphasized the lightness under G. One suggested that no changes would make the mask suitable and reported it to be uncomfortable, hard to donn and restrictive to head movement. The third respondent considered it comfortable but suggested that the oxygen delivery hose be made less stiff and longer so that it would not pull on the mask. The microphone sensitivity was unacceptable, and visor interface was poor. Maintenance evaluation message report comments include:

"Very stable and comfortable in all aspects of flying; some pressure points on bridge of nose. Needs about 2-3 inches more oxygen hose to allow full head movement."

d. A13A - No particular merits of this mask were identified. The bayonet connection was considered to be unsuitable for use with the DH 41-4 helmet. Two of the eight respondents found that it was necessary to tighten the mask past the comfortable limit in order to ensure a good facial seal. Three respondents reported visual field restriction similar to that for the MBU 12/P. The A13A mask was considered to interface poorly with the visors, be unstable and be difficult to donn and doff. Maintenance evaluation message report comments include:

"Mask relatively comfortable. Pilots preferred pate suspension to bayonet fittings. Mask pulled against chin causing some discomfort and restriction to breathing."

The aircrew assessment of the oxygen masks did not indicate that one is clearly superior. The P/Q and W oxygen masks were well accepted. The MBU 12P mask was accepted by operational evaluation aircrew but condemned by maintenance evaluation aircrew. The A13A mask was reported to be deficient more often than the others.

The ratings of the W mask are considered to have suffered as a result of the small number of respondents during the trial. One of the three operational evaluation respondents recorded high frequencies of deficiencies against virtually every assessed characteristic, increasing the lower frequencies awarded by the other participants. Excluding this respondant, the mean score was 92% - higher than for any of the other masks. The responses from the maintenance evaluation showed the least frequency of deficiencies for the W mask in all assessed characteristics excepting visor/mask mating, and the mask was recommended for use in the 434 message report (22).

The poor rating of the helmet attachment of the P/Q mask was due to both the hook (helmet side) and chain (mask side) of this assembly. The hook was reported as being potentially lethal several times in the helmet questionnaire. The chain caused dissatisfaction because of its tendency to tangle when the mask was stored within the helmet. Further aircrew reported that its reflective surface was visually distracting, and there was some concern regarding skin/chain contact during cold weather. Based upon acceptance of the fir-tree connector of the W mask, which is also compatible with the P/Q mask, substitution for the hook and chain assembly would yield an oxygen mask with a combined mean score of 89. The good stability of the P/Q as well as the W masks is due to the restriction to downwards motion provided by the chin with the lower edge of the masks fitting into sulcus (notch).

The A13A oxygen mask with the modified suspension was not scored well by the aircrew and did not illicit any positive comments. The helmet attachment of this mask was particularly criticized. The standard USAF bayonet connectors were not considered suitable for this suspension as the adjustment of the suspension straps was limited by the length of this connector. A shorter stemmed bayonet would likely alleviate this problem. The deficiencies in facial seal and comfort were part of the same problem. In order to achieve a satisfactory seal, the mask had to be tightened past the point of comfort and, conversely, a comfortable mask leaked. The culprit here is most likely the long stemmed bayonet connector which extends far forward of the face at the mask end. As a result, tightening the suspension straps has little effect upon the quality of the seal but tends to force the chin cup and nose piece hard against the wearers face.

The MBU 12P was reported to be deficient in breathing resistance, facial seal, stability, and visual field. The high breathing resistance was noted in the laboratory evaluation. This is an inherent problem of combination inhalation/exhalation valves. Poor facial seal is related to the problem of mask fit described in the maintenance evaluation. When the seal leaked, breathing gas was typically directed towards the eyes - the worst possible type of mask leak. A change to the face seal would probably require rework of the exoskeleton to which it is bonded. The visual field deficiencies of the MBU 12P are attributed to the ready position of the mask and the interference due to the position of the suspension harness in flight. Although the mask was rated well overall, the identified problems will not be easily resolved.

D.1.3 Single vs Dual Visor

Sixteen aircrew favoured a single visor while seven preferred a dual. Three others discussed the merits of both visor systems without indicating a clear preference. Positive characteristics highlighted by respondents include:

a. Single Visor

1. lighter weight
2. lower profile
3. better centre of gravity
4. better visual field
5. either hand actuation
6. less restriction to head movement

b. Dual Visor

1. more flexibility and interchanging not necessary
2. better bird strike protection

Seven aircrew believed that the gradient visor is a good compromise for the dual visor, while five suggested that it is neither dark enough for glare nor light enough for night use. Two aircrew also pointed out that unexpected night flying could leave the user with unsuitable facial protection. It was suggested by two aircrew that little additional protection is provided by a second visor, and by two others who had never used the clear visor that two visors are not needed. The eight aircrew involved in the maintenance evaluation were split evenly between dual and single visor preferences and offered similar rationales.

The increase in birdstrike protection provided by the dual visor system is a result of the flexibility of the system. That is, facial protection is available regardless of ambient light levels. A single clear visor will provide facial protection at all times. The frequency with which the aircrew encounters light levels which would prove fatiguing, bothersome or hazardous determines the utility of a second tinted visor.

The percent increases in the scores of single over dual visor equipped helmets of the same style were derived from the helmet questionnaire results for each assessed characteristic and are presented in Table D12. Several characteristics were affected markedly by the presence of a particular visor system on the PRK 37P shell (DH 200, HGU 33P). Weight, head mobility, visual field and mask interface were affected negatively by the presence of the dual visor. These characteristics, except for mask interface, were a direct result of the physical properties of the visor assemblies. The interface problem was related directly to the oxygen mask worn in that the PRU 36P trim did not mate well with the MBU 12P. The PRU 36P appears to have enhanced ear comfort. The major cause of ear discomfort was a lack of sufficient vertical adjustment. The additional weight of the dual visor assembly may also have displaced the helmets downwards allowing

the ear lobes to enter the earcup rather than have the lower edges of the lobe caught between the earcup flange and the side of the head.

Table D12 - Percent Increase in Scores for Characteristics of Single Over Dual Visor Helmets

Characteristic	DH 200	Helmet HGU 33P	DH 41-4
Comfort			
General	36	- 11	- 10
Donning	12	- 7	- 18
Thermal	17	- 10	- 2
Ear	- 19	- 15	2
Fit	23	- 5	- 16
Weight	27	10	19
Combined	15	- 5	- 4
Visual Field	19	31	24
Profile			
Head Mobility	11	11	22
Helmet Mobility	11	- 1	7
Combined	10	5	14
Stability	1	- 1	- 8
Hearing Protection	4	- 1	- 2
Communication	4	7	11
Visor Mechanism			
Actuation	15	7	- 7
Locking	- 4	2	- 1
Interface	17	29	20
Combined	8	11	- 7
General			
Compatibility	21	- 20	- 15
Lethality	8	6	- 2
Ruggedness	- 4	- 8	- 25
Fitting Time	0	- 4	- 5
Combined	3	- 9	- 15
Comparison to DH 41-2	7	9	22
Overall Mean	7.9	3.2	3.9

The differences between the frequencies of deficiencies for the DH 41-4 equipped with the single visor (CF1) and dual visor (CF2) generally favoured the dual visor excepting weight, visual field and head mobility. The weight and head mobility results relate directly to the increased weight and profile of the CF2 compared to the CF1. The higher frequency of visual field deficiences for the dual visor was not expected in view of laboratory test results and, hence, suggests an aircrew bias.

D.2 Laboratory Evaluation

D.2.1 Impact Protection

The median peak accelerations and pulse durati[illegible] experienced by the

headform are presented in Table D13-A. The values of the GSI and HIC for these median impacts, excluding TPL, are shown in Table D13-B. Generally the lower GSI and HIC values correspond to lower peak accelerations.

Table D13 - Mean Performance of Aviator Helmets
During Impact at 90 Joules

A. Peak Acceleration (a max (G)) & Peak Acceleration Range (R (G))

	Crown		Rear		Side		Front			
							Single Visor		Dual Visor	
Helmet	a max	R	a max	R	a max	R	a max	R	a max	R
DH 186	184	75	268	65	226	83	162	89	-	-
DH 200	178	24	538	37	196	1	206	54	344	-
HGU 33P (V-Tec)	161	18	287	473	207	140	249	337	286	194
HGU 33P (TPL)	202	15	196	8	224	10	-	-	153	38
DH 41-4	159	48	296	499	179	85	567	90	300	38

B. Gadd Severity Index (GSI) and Head Injury Criteria (HIC)

	Crown		Rear		Side		Front			
							Single Visor		Dual Visor	
Helmet	GSI	HIC	GSI	HIC	GSI	HIC	GSI	HIC	GSI	HIC
DH 186	1007	841	1809	1572	1289	1001	851	849	N/A	
DH 200	1026	882	3104	*	1088	939	892	756	2101	1544
HGU 33P	861	733	1135	944	1236	1093	1285	978	1962	1607
DH 41-4	909	765	1458	1165	1157	939	4088	*	1908	1401

* Computation bounds of program exceeded.

D.2.2 Hearing Protection

The sound attenuation characteristics of the four helmets are presented in Table D14. The calculated sound pressure levels in the CF-5 and CF-104 aircraft are shown in Table D15. The greatest noise hazard occurs at 250 Hz for both aircraft with all of the helmets. Maximum daily exposure times, as recommended by ISO (23), are less than fourteen minutes in the worst case CF-5 sonic environment (altitude 91 m; airspeed 420 knots IAS; air condition - full hot). The DH 186 and DH 200 helmets have maximum daily exposure times of two hours in the worst case CF-104 sonic environment (altitude - 2440 m; airspeed - 400 knots IAS; dump valve - open), compared to 45 minutes for the HGU 33P and DH 41-4.

Table D14 - Sound Attenuation (x -) of Aircrew Helmets (dB)

	Frequency (Hz)								
Helmet	125	250	500	1000	2000	3150	4000	6300	8000
DH 186	8.6	5.9	23.2	18.6	25.9	37.4	43.4	40.4	31.1
DH 200	7.4	5.7	18.9	21.1	32.1	38.0	43.7	42.1	39.0
HGU 33P	4.2	3.9	10.6	16.2	30.1	41.6	47.9	40.4	36.3
DH 41-4	4.8	4.4	11.1	17.1	25.4	32.3	39.0	34.0	29.5

Table D15 - Calculated Sound Pressure Levels (dB) Under Aircrew Helmets In the Worst Case Noise Condition in the CF-104 and CF-5 Aircraft

Helmet	125 CF-104	125 CF-5	250 CF-104	250 CF-5	500 CF-104	500 CF-5	1000 CF-104	1000 CF-5	2000 CF-104	2000 CF-5
DH 186	93	89	94	106	83	90	87	95	81	87
DH 200	95	91	94	106	87	94	85	93	75	81
HGU 33P	98	91	96	108	95	102	90	98	77	83
DH 41-4	97	93	96	108	95	102	89	97	82	88

D.2.3 Facial Protection and Retention During Windblast

The mean anterior and posterior displacements for each helmet/mask test condition are shown in Table D16. The single visor PRK-37P deviations (HGU 33P, DH 200 and DH 186) were displaced more than the corresponding dual visor versions. The DH 41-4, the most stable helmet overall, was displaced the least under test conditions and in all configurations excepting the MBU 12P mask. The least helmet displacement generally occured with the MBU 12P and A13A masks.

The contact helmets (HGU 33P, DH 200) were both displaced more than the suspension helmets (DH 41-4, DH 186). The DH 200 was observed to be more stable than the HGU 33P overall. A secondary investigation indicated that this difference could be attributed to the nape strap rather than the helmet liner.

The PRU 36/P visor was typically displaced upwards during windblast so that the eyes and upper face were exposed. The EEK 4AP visor cover split on two trials, releasing the visor and exposing the face. Both the CF1 and CF2 performed well during windblast tests.

Table D16 - Mean Helmet Displacement (cm)
During Pulse Windblasts

Helmet	CAS (Knots)	Ref. Point*	No Mask	Oxygen Mask P/Q	Oxygen Mask MBU 12P	Oxygen Mask A13A	Oxygen Mask W	Mean
DH 186	450	A	1.40	1.27	1.02	0.94	0.71	0.99
		P	0.79	0.64	0.23	0.41	0.79	
	560	A	2.74	1.91	1.12	1.27	1.09	
		P	0.89	0.91	0.41	0.48	1.09	
DH 200S	450	A	2.54	1.78	0.38	0.56	5.08	1.68
		P	0.15	0.00	0.76	0.08	1.91	
	560	A	3.56	2.24	0.56	0.61	9.53	
		P	0.30	0.30	1.52	0.38	4.45	
DH 200D	450	A	2.24	2.24	0.15	0.91	1.91	1.04
		P	-0.15	0.76	0.00	0.08	0.30	
	560	A	3.81	3.05	0.61	1.30	2.54	
		P	-0.38	-0.08	0.08	0.15	0.97	
HGU 33PS	450	A	3.18	2.84	1.91	2.24	1.14	1.98
		P	1.02	1.02	0.64	1.35	0.61	
	560	A	5.72	4.45	2.24	2.08	2.69	
		P	1.27	1.12	1.12	1.42	1.73	
HGU 33PD	450	A	2.62	1.91	1.91	1.52	1.78	1.47
		P	1.35	0.00	0.99	0.64	0.00	
	560	A	4.06	1.91	1.73	2.03	2.24	
		P	1.78	0.33	1.02	0.97	0.64	
DH 41-4S	450	A	0.30	1.12	0.00	0.00	-	0.79
		P	0.51	0.15	0.46	-0.64	-	
	560	A	3.18	1.55	2.54	0.64	-	
		P	0.33	0.46	-0.64	0.15	-	
DH 41-4D	450	A	0.00	1.27	0.00	0.00	0.00	0.41
		P	-0.33	0.00	1.52	0.15	0.00	
	560	A	0.64	1.40	1.52	0.38	0.51	
		P	0.00	0.00	0.38	0.15	0.08	
MEAN			1.60	1.22	0.84	0.76	1.68	

* A - Anterior; P - Posterior

D.2.4 Field of Vision

The angular visual area loss for each subject caused by each helmet type, relative to the loss experienced with the DH-186, is presented in Table D17. The mean field loss ratios indicate that the DH 41-4D is the least restrictive helmet, the DH 200D is the most restrictive helmet and the remainder are comparable to the DH 186. The degree to which each assembly interfered was inconsistent from subject to subject, except that all subjects had the smallest visual area when wearing the DH 200D.

Table D17 - Percent Visual Field Loss for Aviator Helmets
Relative to Loss With DH 186

	Subject						
Helmet	1	2	3	4	5	6	Mean
DH 186*	100 (0.51)	100 (1.31)	100 (0.43)	100 (0.59)	100 (0.83)	100 (0.63)	100 (0.71)
DH 200S	-	-	-	82	103	68	84
HGU 33S	84	115	106	-	-	-	94
DH 41-4S	94	61	119	-	-	-	91
DH 200D	135	147	180	-	-	-	154
HGU 33PD	-	-	-	118	130	55	101
DH 41-4D	-	-	-	74	84	63	74

* Loss in rad shown in parenthesis.

D.2.5 Centre of Gravity and Weight

The position of the centre of gravity for each medium size helmet is shown in Table D18. The centres of gravity of the DH 186 and DH 200 are closest to that of the naked headform. The greatest forward angular displacement of the centre of gravity is seen for the DH 186 and DH 200D.

Table D18 - Centre of Gravity Position of Medium Sized
Helmets With Outer Visor Deployed

Helmet	Radius + (cm)	Angle (rad) *
DH 186	3.63	0.30
DH 200S	3.61	0.06
HGU 33PS	5.08	-0.14
DH 41-4S	3.84	0
DH 200D	4.11	0.23
HGU 33PD	5.54	-0.02
DH 41-4D	4.95	-0.03

\+ Distance from headform (origin) to helmet centre of gravity.

* Direction from headform to helmet centre of gravity relative to vertical (zero) axis of the headform, positive defined forward of vertical axis.

The mean position of the centres of gravity for all sizes of oxygen masks are shown in Table D19. The centres of gravity of the MBU 12P and A13A are closest to that of the naked headform, while similar angular displacements were recorded for all oxygen masks.

Table D19 - Mean Centre of Gravity Position of
All Sizes of Oxygen Masks

Mask	Radius + (cm)	Angle * (rad)
W	16.5	2.07
P/Q	16.4	2.14
MBU 12/P	12.0	2.21
A13A	13.0	2.09

+ Distance from headform (origin) to helmet centre of gravity.

* Direction from headform to helmet centre of gravity relative to vertical (zero) axis of headform, positive defined forward of vertical axis.

The weights of the helmets and masks are shown in Table D20, and Table D21, respectively. The DH 200S is the lightest in both medium and large sizes, followed closely by the DH 186. The dual visors were typically 1.5 N heavier than the single visors. The lightest complete oxygen mask assembly, "W", was approximately half as heavy as the A13A mask.

Table D20 - Weight (N) of Helmets Without
Oxygen Mask Connection Devices

Helmet	Medium	Large
DH 186 *	11.3	11.3
DH 200S	10.8	11.3
DH 200D	12.1	12.8
HGU 33PS	11.8	12.2
HGU 33PD	13.3	13.7
DH 41-4S	12.1	12.6
DH 41-4D	14.1	14.3

*Universal size

Table D21 - Mean Weight (N) of All Sizes of
Aviators Oxygen Masks

Type	Mask	Connectors	Total
W	2.49	0.27	2.76
P/Q	2.62	0.49	3.11
MBU 12/P	2.76	1.16	3.91
A13A	3.91	1.16	5.07

The position of the helmet/mask centre of gravity effects the moment arm of the gravitational and accelerative forces. The quantity of concern is, then, the moment caused by the helmet/mask. Table D22 shows relative moment values for helmet/mask configurations with the head positioned erect (most common position) and for maximum moment (arm between centres of gravity of helmet/mask and head oriented perpendicular to the direction of acceleration).

Table D22 - Moment (N cm) About Centre of Gravity of 50 Percentile Head Due to Presence of Helmet and Oxygen Mask Under Gravitational Force

	Erect Head				Maximum Moment* Head Position			
Helmet	W	P/Q	MBU12P	A13A	W	P/Q	MBU12P	A13A
186	52.1	55	49.7	69.3	54.9	56.2	50.9	69.6
200S	42.3	45.2	39.3	59.5	45.6	46.6	41.4	59.8
33S	31.6	34.5	29.2	48.4	49.0	46.9	42.8	55.4
41-4S	40.0	42.9	37.6	57.2	47.0	46.9	41.9	58.8
200D	51.3	54.2	48.9	68.5	57.8	58.1	53.0	77.1
33D	38.5	41.4	36.1	55.7	46.6	62.0	58.2	69.0
41-4D	37.9	40.8	35.5	55.1	61.2	58.8	54.8	66.3

* Arm between centres of gravity of helmet/mask and head oriented perpendicular to acceleration direction.

D.2.6 Profile

The profile offsets caused by the helmets are shown in Table D23. The PRK 37P derivatives (DH 186, DH 200, HGU 33P) with a given visor system resulted in similar profile offsets, except for slightly greater vertical offset of the DH 186. The dual visor equipped helmets had smaller vertical and longitudinal offsets than the single visor equipped helmets. The least lateral offset was noted for the DH 41-4 (either visor).

Table D23 - Increase in Profile (cm) Resulting from Aviators Helmets

Size	Dimension	DH 186*	DH 200S	HGU 33PS	DH 41-4S	DH 200D	HGU 33PD	DH 41-4D
	Vertical	NA	5.5	5.9	6.1	5.1	4.8	5.4
Medium	Lateral	NA	10.9	10.8	8.6	10.8	10.8	8.6
	Longitudinal	NA	5.9	6.0	6.8	4.7	5.1	7.1
	Vertical	6.6	6.2	6.3	7.2	5.7	5.6	6.6
Large	Lateral	11.1	11.3	11.2	10.0	11.3	11.3	10.4
	Longitudinal	7.8	7.9	7.9	7.7	7.4	7.6	7.8

* Universal size

D.3 Maintenance Evaluations

D.3.1 Helmets

It was extremely difficult to mount long bayonet receivers on the DH 186 helmet shell and, in the end, holes were drilled through both the inner and outer shells to facilitate this mounting. The presence of the receiver mounting screws added to the disassembly and reassembly time required for completion of fitting. The RT cord was approximately two inches too short to allow all pilots complete freedom of head movement and was re-routed internally to accommodate this requirement. The matt black paint over the kevlar inner helmet tended to chip and by the end of the trial all of the helmets were missing significant quantities of paint about the edge of the inner helmet. Fitting of the suspension straps and earcups was easily accomplished, however problems were encountered in fitting very large heads. One aircrew (pilot) could not be fitted while any of the frontal or occipital fitting pads were in place. Four aircrew refused to wear the helmet at all and one returned it stating it was a flight

safety hazard. No particular oxygen mask compatibility problems beyond that of the bayonet receivers were noted.

The fitting of the DH 200 helmet was usually accomplished in less than ten minutes, excluding time for oxygen mask adjustment. Persistent hot spots were reported in the liner by some participants. Pressure points were also reported in the ear area and no satisfactory remedy was discovered. Part of the problem was attributed to the simplex skull caps which held the ears flat against the side of the head causing the edges of the earlobes to be pinched between the flange of the earcups and the side of the head. Removal of the skull caps alleviated this problem for some aircrew. The earcups of both this helmet and the HGU 33P were reported to occasionally come free of the velcro closure which secured them to the sides of the helmet shell during donning/doffing necessitating repositioning of the velcro spacers. The leather edgerolls of the helmets started to show signs of wear at the base of the temporal region and some actually wore through. The RT cord of this helmet and the HGU 33P were routed out the left side of the helmet rather than the customary right side causing concern among some participants with regard to seat/man separation problems. The helmet interfaced well with all oxygen masks.

The fitting of the V-Tec Custom Fit Interliner in the HGU 33P helmet took twenty minutes to complete, however approximately twenty percent had to be refitted because of voids, or excessive liner expansion during the fitting procedure. The nape strap was removed for several participants as it was not long enough to allow the helmet to be donned. The problems of ear discomfort, earcup "wandering", RT cord routing and edgeroll wear which occurred in the DH 200 also occurred with this helmet. The helmet interfaced well with all oxygen masks.

The DH 41-4 helmet posed no fitting problems not already encountered with the DH 41-2, but elusive pressure points were no less common. The helmet interfaced well with the P/Q and W masks, however it was very difficult to adjust the MBU 12/P and A13A oxygen masks to fit this helmet because of the forward location of the bayonet receiver on the cheek flap which compounded the fitting problems of these oxygen masks.

D.3.2 Oxygen Masks

Fitting of the MBU 12/P oxygen mask was difficult. The fixed dimension of the nose piece meant that only aircrew with the correct cheek to bridge of nose height would get a positive seal at mask pressures greater than 10 inches of water gauge without discomfort. Two aircrew could not be satisfactorily fitted. Adjustment of the mask angle to the face was easily accomplished by the complimentary adjustments available in the bayonet receiver and the suspension harness. Similarly fore and aft (tightening) positioning was readily accomplished. The mask microphone often caused the wearer discomfort due to contact with the mouth.

The only maintenance difficulty with the MBU 12P is the changing of the combination inhalation/exhalation valve. Changing this valve required stripping of the oxygen mask of the oxygen delivery hose and microphone, however, no special tools are required.

Selection of a correctly fitting P/Q mask was simple, but adjustment of the attachment chain length was not. Shortening the chain is accomplished by removing the rivets securing the chain to the yoke harness, cutting the chain to the correct length, and rivetting the chain to the yoke harness. Lengthening the chain requires that the chains also be separated from the D-ring at the other end, and a new length of chain added between the yoke harness and the D-ring. Adjustment of the mask position in pitch is unnecessary and in the longitudinal direction is accomplished by the aircrew adjusting the length of the

helmet mounted hook. The mask always held pressure greater than 14 inches of water gauge (26 mm Hg).

Maintenance of the P/Q mask is not difficult. The replacement of valves and microphone is straightforward. The microphones were susceptible to moisture and one of the masks on the long term evaluation became unserviceable. The exhalation valve compensation tube must be inserted carefully to avoid damage to the oxygen mask rubber.

The selection of the correct W oxygen mask for aircrew was straightforward. Adjustment of mask position is required only in the longitudinal direction and is easily accomplished by insertion of the male fixture connector to the appropriate depth into the female connector. Replacement of valves could have been easily accomplished by removal of the valve block, although care is required in reassembly to ensure that the seal is made between the face seal, valve block and exoskeleton. The mask held pressure in excess of 14 inches of water gauge.

Several W mask deficiencies came to light during the long term evaluation. The silicone rubber of the reflected seal at the bridge of the nose tore on three of the masks used during the evaluation. The plastic covering of the wire connecting the fir-tree to the yoke harness wore through where it passed over the harness guides. The wire broke due to fatigue at the swaged connection to the yoke harness.

Aircrew made use of their own A13A mask, changing only the suspension. Hence, selection of the appropriate mask was not a problem. The adjustment and fitting of the mask was straighforward and easily accomplished on those helmets incorporating the PRK-37P shell. The mask did not integrate well with the DH 41-4 as the cheek flap mounting of the bayonet receivers caused the bayonets to protrude well forward so that tightening of the suspension straps tended to flatten the mask against the wearer's face rather than tighten it. There were no maintenance difficulties encountered.

D.3.3 Visors

The USN EEK 4AP single visor system showed many maintenance deficiencies. The visor cover tended to split from the visor knob guide forward to the leading edge. The visor knob retaining screw sheared off frequently, occasionally in flight. The same retaining screw could scratch aircraft canopies when the visor was not deployed. The visor bases had to be cut away at the sides to accommodate the mask suspension straps and bayonets of the MBU 12P and modified A13A.

No maintenance or fitting deficiencies were noted relating directly to the PRU 36P visor assembly. However the mounting locations which were dimpled into the surface of the helmet did not always align with the visor assembly mounting screw locations.

The CF1 single visor system did not function well. The visor had a tendency to stick in the visor tracks and jam even when well lubricated. The visor did not mate well with the oxygen mask resulting in large gaps which could not be eliminated. Two visor covers cracked from the visor button guide to the leading edge.

The CF2 dual visor system performed well and no maintenance or fitting deficiencies were recorded.